Government Publications

RESEARCH HIGHLIGHT

March 2005

Technical Series 05-105

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TESTING THE ADHESION OF AIR-BARRIER MEMBRANES IN WALL ASSEMBLIES

INTRODUCTION

Structural integrity of the air barrier is one of the requirements identified in the *1995 National Building Code of Canada* (NBCC). This means that an air-barrier system in a structure that is exposed to wind load should transfer the load to the structure. Further, the air-barrier system should be designed and built to resist specified wind loads.

One of the critical performance characteristics of air-barrier materials is long-term adhesion. An air-barrier system must be able to resist peak wind-loads, stack-pressure effects and sustained pressurization loads over the long-term without showing signs of detachment, rupturing, deflection or creep-load failure.

Currently, there is limited information about adhering air-barrier materials to an underlying surface, or how adhesion changes both over time and through exposure to different environmental conditions.

Figure 1: The hand-operated digital fastener tester used for tensile adhesion.

RESEARCH PROJECT

Retro-Specs Consultants Ltd., Winnipeg, conducted this research for Canada Mortgage and Housing Corporation (CMHC).

Objectives

- Evaluate and compare the adhesion performance between membranes and substrates of different air-barrier membrane materials and to determine whether time, environmental conditions or the type of primer used together with the membrane affect adhesion.
- Provide a benchmark for membrane–substrate adhesion that could provide both a reference point for comparison with other test results and quantifiable performance requirements that could be applied in the field.

Scope of work

1. Establish benchmarks for the adhesion strength between an air-barrier membrane and substrate.
2. Establish adhesion strength between an air-barrier membrane and substrate after exposure to different environmental conditions and to identify changes in adhesion performance compared to project benchmarks. This phase consisted of three mutually exclusive sections:

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- Exposure to low temperature.
- Exposure to high temperature and high humidity.
- Water saturation.

3. Establish adhesion strength between an air-barrier membrane and substrate after predetermined time intervals and determine whether adhesion performance increased, decreased or remained constant.

Environmental variables

To determine the effect of environmental conditions—cold temperatures, high temperature-high RH and wetting of substrate—on the performance of membrane–substrate adhesion strength of air-barrier systems. To make this determination, samples were either:

Exposed to a temperature of -20°C (-4°F) for 48 hours

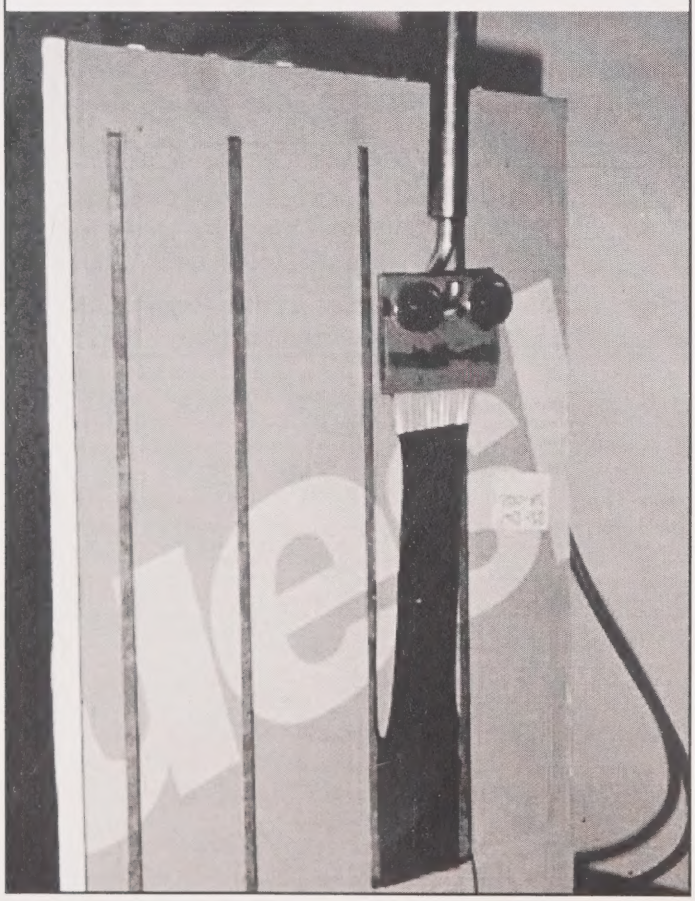
or

Exposed to a temperature of 25°C (77°F) at 95 per cent RH for 60 days

or

Saturated with water for eight days, after which the substrate was allowed to dry. Following each exposure condition, the researchers measured adhesion strength between the air-barrier material and substrate at room temperature.

Figure 2: Fast peel test



Sampling

A total of 375 specimens were constructed. Each of the 32 membrane-substrate combinations was considered a "system."

Construction of samples

Eight different membrane systems were considered:

- five self-adhesive sheet membrane systems
- one torch-applied sheet membrane system
- two liquid-membrane systems.

Each membrane system was tested on four substrates:

- exterior drywall
- glass-faced gypsum board
- poured-in-place concrete
- concrete block

The eight membrane systems and four substrates made a total test sample of 32 different air-barrier systems.

All specimens were constructed and membranes installed in strict accordance with manufacturers' recommendations under controlled laboratory conditions. Self-adhesive sheet membranes and torch-applied sheet membranes were installed over the complete surface of one side of the substrate, with a 3.8-cm (1.5-in.), folded, salvage-edge at the top of the sample to facilitate peel-adhesion testing. The specimens were allowed to cure for a minimum of 24 hours before conditioning or testing.

To prepare the liquid-membrane specimens, a skim coat of liquid-membrane material was applied over the complete surface of one side of the substrate. Liquid membranes were allowed to cure for a minimum of seven days before conditioning or testing.

Membrane adhesion to the substrate was tested three ways

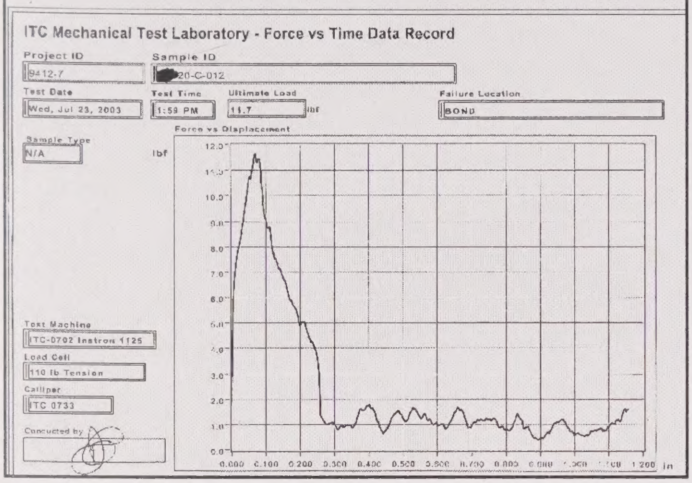
1. strength of tensile adhesion to the substrate
2. slow-peel resistance
3. fast-peel resistance.

Tensile adhesion testing was conducted in general accordance with ASTM D 4541, using a hand-operated, digital-fastener tester that applied a tensile load to the specimen.

Slow-peel resistance testing

Test specimens were mounted vertically on the wall and a 100-g (3.5-oz.) load was clamped onto the salvage edge on a strip of the membrane, placing a 180-degree peel-load against the salvage edge. The length of the portion of the strip that detached and peeled from the substrate was measured and recorded daily.

Figure 3: Example of tensile resistance graph showing failure load.



Fast-peel resistance testing

The rigid substrate of the test specimen was clamped to a vertical alignment plate mounted on the base of a universal testing machine equipped with a tension-load cell. The salvage edge on a strip of the membrane was folded back 180 degrees and firmly gripped with a specially fabricated clamp attached to the load-cell through a tension rod. The loading-cell was zeroed and the test machine was started to peel the strip from the rigid substrate. The force required to peel the strip from the substrate was recorded on graphs.

No sample was exposed to more than one of the conditioning variables. In other words, a specimen that was "frozen" was not then saturated—a different specimen was built and saturated.

SIGNIFICANT FINDINGS

- When installed under controlled laboratory conditions and without exposure to any of the control variables, the torch-applied sheet membrane, liquid membranes and self-adhesive sheet membranes–solvent-based primers consistently withstood tensile loads in excess of 172 kPa (25.0 psi) without detaching from the substrate.
- Some specimens of torch-applied sheet membranes, liquid membranes and self-adhesive sheet membranes-solent-based primers, remained adhered at tensile loads as high as 370 kPa (53.8 psi), 450 kPa (65.2 psi) and 278 kPa (40.4 psi).
- Self-adhesive sheet membranes–water-based primers consistently withstood tensile loads up to 103 kPa (15.0 psi) without detaching from the substrate, although the range between the high 220 kPa (32.0 psi) and low 50 kPa (7.2 psi) test results was significantly larger than those of the other membranes.
- Under controlled laboratory conditions and without exposure to any control variables, and with a sustained 100-g load clamped onto the membrane's salvage edge, adhesion of self-adhesive sheet membranes was affected by the load in the short-term, as the membrane either peeled from the substrate or the polyethylene carrier-sheet separated from the bitumen (which remained adhered to the substrate) within the 28-day, slow-peel resistance test period.
- The torch-applied sheet membrane and liquid membranes exhibited good short-term resistance to the sustained load, as there was little to no detachment of these membranes during the 28-day test period.
- When installed under controlled laboratory conditions and without exposure to any of the control variables, a peak-peel load greater than 1.93 kN/m (11.0 lbf/in.) was generally required to peel the torch-applied sheet membrane, asphalt-based liquid membrane and self-adhesive sheet membranes–solvent-based primers from the substrate during fast-peel resistance testing, with some specimens remaining adhered at loads in excess of 6.13 kN/m (35.0 lbf/in.).
- During fast-peel resistance testing, self-adhesive sheet membranes–water-based primers and the rubber-based liquid membrane consistently peeled from the substrate at peak-peel loads less than 1.93 kN/m (11.0 lbf/in.) and as low as 0.75 kN/m (4.3 lbf/in.) and 0.19 kN/m (1.1 lbf/in.).
- A membrane's tensile-adhesion test results did not necessarily correlate with its peel-resistance test results.
- Adhesion characteristics of self-adhesive sheet membranes under controlled laboratory conditions and without exposure to any of the control variables depended on the primer or primer–substrate combination used. Self-adhesive sheet membranes consistently withstood higher tensile and peel loads without detaching from the substrate when a solvent-based primer was used compared with a water-based primer in the short-term.
- Fast-peel resistance of self-adhesive sheet membranes/solvent-based primers *decreased* over a 60-day time period, by as much as

Figure 4: Adhesive failure in the field

19% on one product and 63% on another. Fast-peel resistance of self-adhesive sheet membranes/water-based primers *increased* over a 60-day time period, by as much as 14% on one, 25% on another and 97% on a product using a specially-formulated primer.

- It did not appear that exposure to a given control variable had a similar effect on all mem-branes or all membranes within a particular membrane class (self-adhesive, torch-applied, etc.), or even an individual membrane. The effect of each of the three conditioning cycles—low-temperature, high-temperature–high-humidity and saturation—on tensile adhesion and peel-resistance was generally specific to the combination of membrane, primer, and substrate.
- For most membranes, the tensile strength of adhesion between the membrane and substrate when installed on either drywall or glass-faced gypsum board was greater than the tensile strength of the drywall and glass-faced gypsum board material.

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